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(54) Valve control

(57) Apparatus controlling the opening and closing of a valve 16 in accordance with the relative phase of two cams 25, 26 each fixedly mounted on one of two separate, contra-rotating, camshafts 22, 23 respectively, includes a dual cam-follower 27 having two spaced-apart contact positions 31, 32 for contacting the two cams respectively. The dual cam-follower 27 is pivoted at its centre 28 to an intermediate member 29, which is mounted on the top end of the valve-stem 35. There is lost motion between them against a spring 47.

When the contact position 32 is riding on the high-lift lobe 54 of the cam 26, the lost motion is taken up and any increase in lift of contact position 31 due to cam 25 depresses the valve stem and opens the valve.

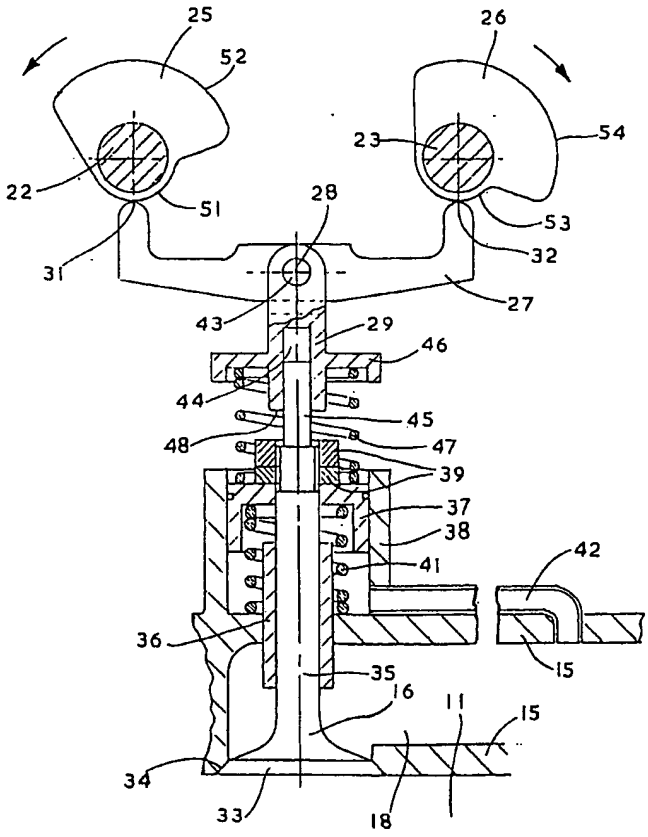

FIG. 2.

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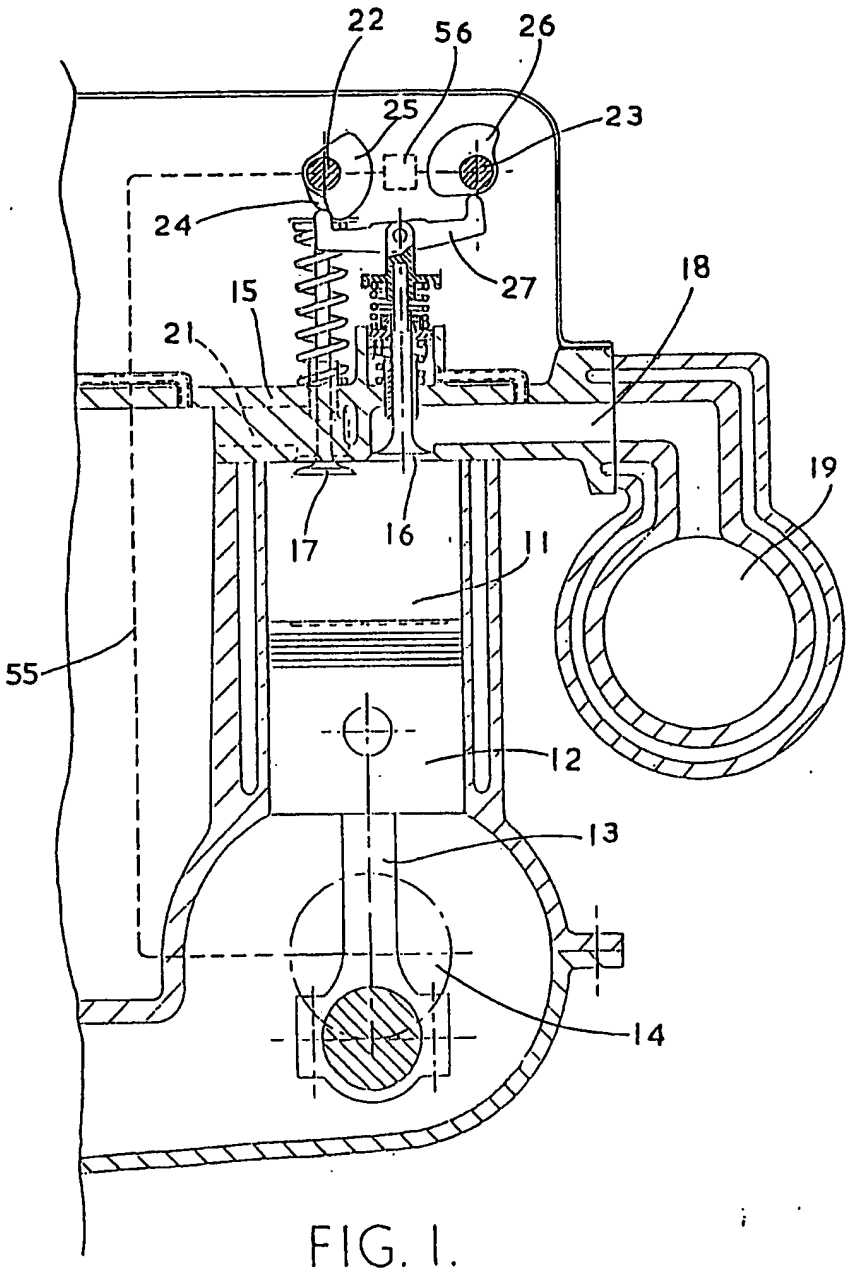

FIG. 1.

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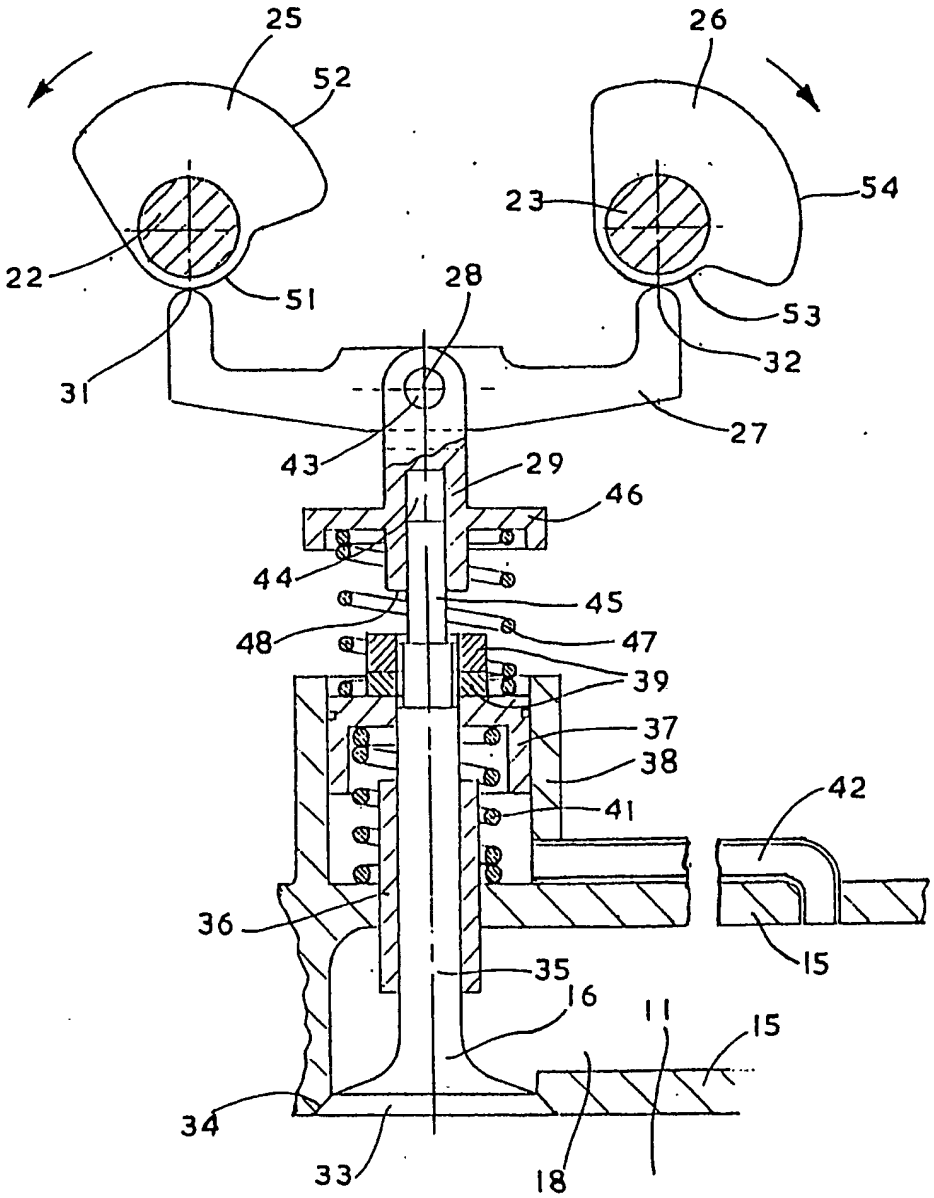

FIG. 2.

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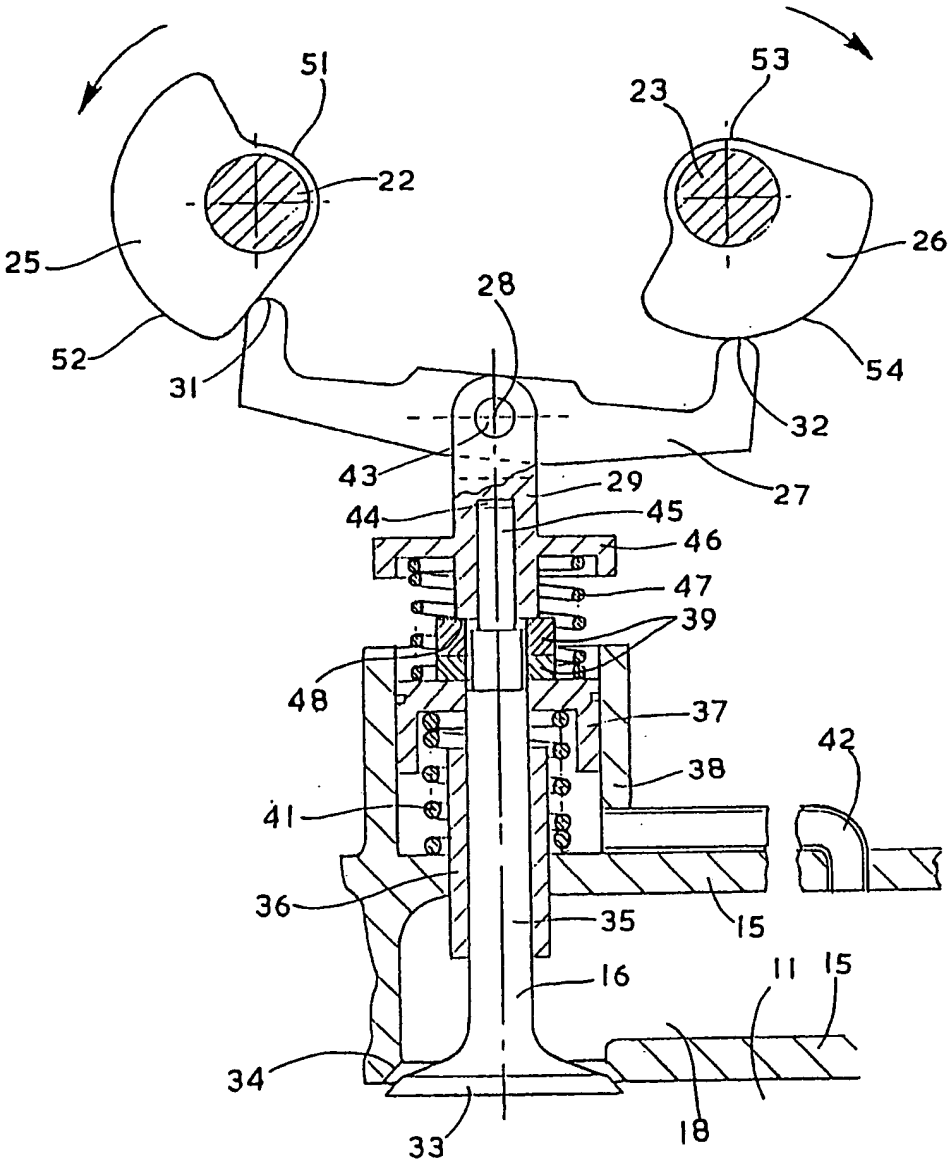

FIG. 3.

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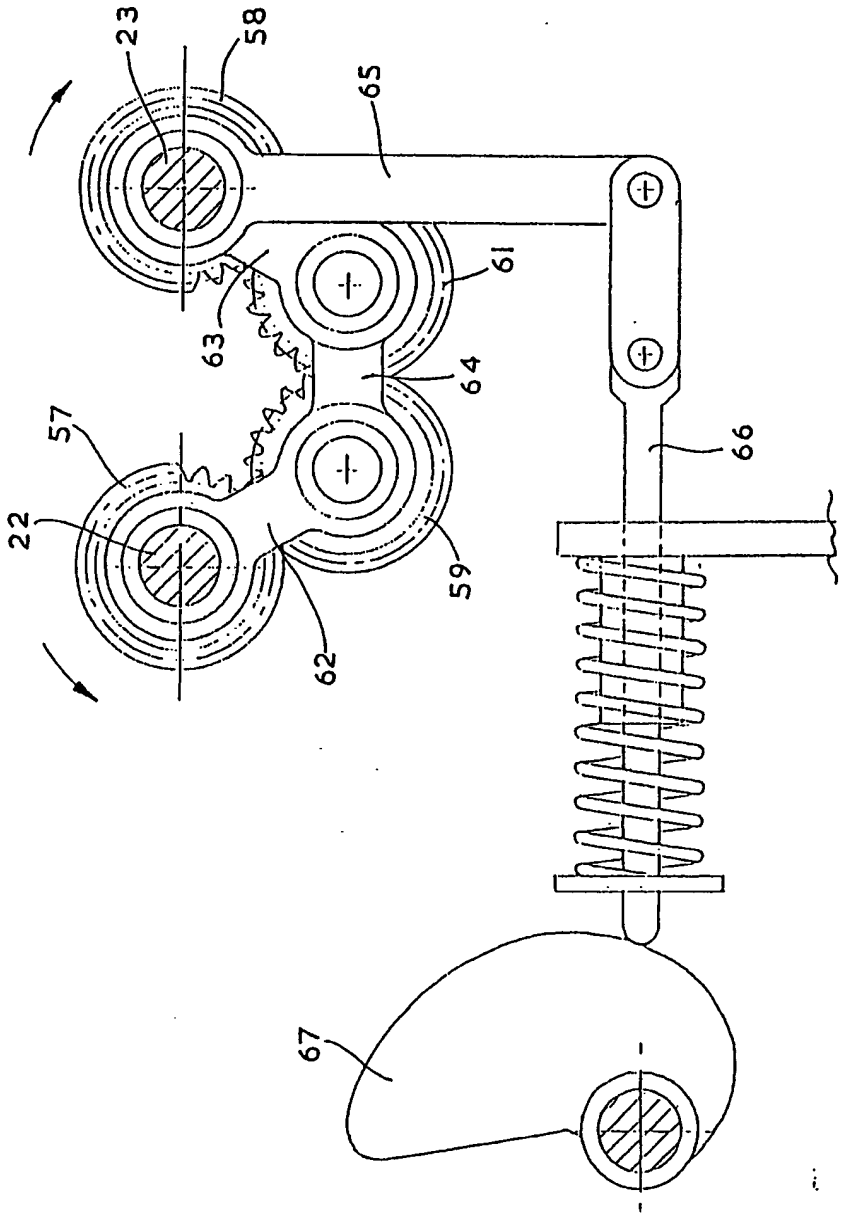

FIG. 4.

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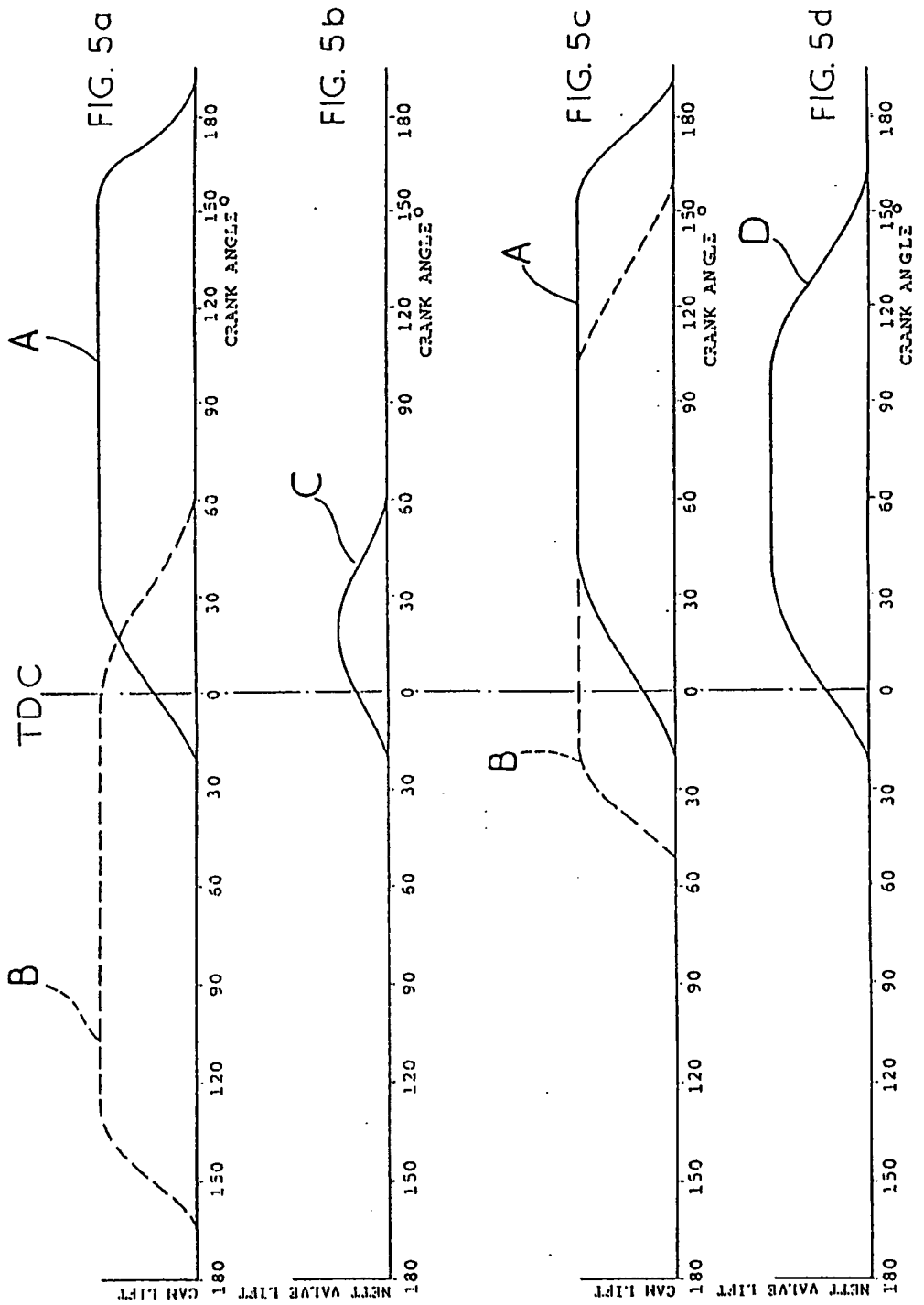

FIG. 5.

SPECIFICATION

Apparatus for controlling the opening and closing of a valve

The invention relates to apparatus for controlling the opening and closing of a valve.

For example, in a positive displacement expansion unit the volume of which varies cyclically, working fluid is admitted periodically to do work by expanding, and thereby drive the expansion unit. It is in certain circumstances desirable to adjust the "cut-off ratio" of the unit. The cut-off ratio is defined as the ratio of the expansion unit volume when the working fluid admission valve closes to the maximum volume of the expansion unit during its cycle.

The admission or inlet valve will normally need to open at a fixed phase with respect to top dead centre of the unit, and the point at which the valve closes will then have to be adjusted with respect to this opening point.

The above is one example of the circumstances in which the present invention may be usefully applied, although the invention is of wider application.

The present invention provides, in one of its aspects, apparatus for controlling the opening and closing of a valve in dependence upon the relative phase of two rotatable cams, comprising:

a dual cam-follower having two input positions spaced apart and adapted to follow the two cams respectively, and an output position spaced apart from each of the aforesaid two input positions and connected to move the valve to open and close,

the movement of the output position representing the sum or resultant of the movements of the two input positions in response to the rotation of the two cams,

there being lost motion between the movement of the output position of the dual cam-follower and the movement of the valve away from its closed position,

such that the valve is open only when the sum or resultant of the movements of the two input positions of the dual cam-follower exceeds a predetermined minimum.

Preferably the apparatus includes an intermediate member connected between the output position of the dual cam-follower and the valve, there being lost motion between the intermediate member and the valve.

Preferably the dual cam-follower can pivot with respect to the intermediate member at the output position.

The dual cam-follower may comprise a single lever having the two input positions spaced apart therealong and the output position intermediate the two input positions.

Preferably the output position is substantially equidistant from each of the two input positions.

A specific embodiment of the invention will now be described by way of example, and with reference to the accompanying drawings, in which:

Figure 1 is a section through a piston and cylinder expansion unit to which the invention has been applied;

Figure 2 is an enlarged section through the inlet valve and its actuating gear with the valve in the closed position;

Figure 3 is similar to Figure 2 but shows the valve starting to open;

Figure 4 shows part of the associated camshaft driving gear;

Figures 5a to 5d illustrate graphically the relative movements of the two cams.

The expansion unit illustrated in Figure 1 essentially comprises a cylinder 11 in which reciprocates a piston 12 attached by a connecting-rod 13 to a crankshaft 14. The cylinder head 15 is provided with an inlet valve 16 and an exhaust valve 17, both valves being poppet-valves. The inlet valve admits working fluid (which may be hot air under pressure) via an inlet pipe 18 from an inlet supply passage 19. The exhaust valve 17 allows exhaust air to escape through an exhaust pipe 21.

The opening and closing of the two valves 16 and 17 is effected by two camshafts 22 and 23. The camshaft 22 carries an exhaust cam 24 which alone controls the opening and closing of exhaust valve 17, and a first inlet cam 25. The second camshaft 23 carries a second inlet cam 26. The cams 25 and 26 together control the opening and closing of inlet valve 16 by means of a dual cam-follower 27 which contacts both of the cams 25 and 26 and is also connected to move the inlet valve 16.

Figures 2 and 3 show the inlet valve and its control gear on an enlarged scale.

The dual cam-follower 27 comprises an elongated lever which is pivoted at its centre 28 to an intermediate member 29. The cam-follower has at each end an input position, both spaced equally from the centre 25. The first input position 31 contacts the cam 25, and the second position 32 contacts the cam 26. Each input position is provided by the rounded tip of an end part of the cam-follower, the two end parts projecting substantially at right-angles to the length of the cam-follower lever to ensure that the latter does not foul the lobes of the cams as they rotate. The centre 28 of the cam-follower acts as an output position, at which it is connected to operate the valve 16.

The valve 16 comprises a head 33 which co-operates with a valve seat 34 in the cylinder head 15, and an elongated valve stem 35. The valve stem slides in a valve guide 36. Towards the upper end of the valve stem are secured two lock-nuts 39, against which is located a balancing piston 37 which slides in a balancing cylinder 35 projecting upwardly

from the cylinder head 15. A compression spring 41 below the balancing piston 37 urges it upwards against the locknuts 39 and also urges the valve 16 upwards into its closed position. The balancing cylinder 38 is supplied with working fluid from the inlet pipe 18 through an auxiliary pipe 42, so that any resistance to the closing of valve 16 due to fluid pressure above its head 33 is more than balanced by fluid pressure upwards on piston 37.

The upper end of the intermediate member 29 carries a cross-pin 43 on which the the cam-follower lever 27 is pivoted at its centre 28. The lower end of the intermediate member 29 carries a bore 44 in which slides a smooth locating peg 45 forming the uppermost part of the valve stem 35. The intermediate member 29 has a flange 46 which contacts the top end of a compression spring 47, the lower end of which contacts the top of balancing piston 37. The member 29 is thus urged upwardly by the spring 47, so that each of the two contact positions of the cam-follower 27 is urged into contact with its respective associated cam.

The bore 44 in member 29 is sufficiently long that the top of peg 45 does not touch the inner end of the bore when the spring 47 is compressed. Instead, the bottom end face 48 of the member 29 contacts the uppermost locknut 39.

Cam 25 has a low-lift portion 51 (which allows the associated contact position 31 of the cam-follower to rise), and a high-lift portion 52 (which depresses the contact position 31 of the cam-follower). Likewise cam 26 has a low lift portion 53 (which allows the associated contact position 32 of the cam-follower to rise), and a high-lift portion 54 (which depresses the associated contact position 32 of the cam-follower). (The terms "low-lift" and "high-lift" are used because these are conventional in relation to the shape of cam lobes, although in this particular example the cam-follower is depressed instead of lifted). On both cams 25 and 26, the shapes of the transition faces joining the "high lift" portion (52 or 54) and the "low lift" portion (51 or 53) are as steep as possible, subject to being able to move the cam-follower 27 and valve 16 satisfactorily. As illustrated in Figure 2, cam 25 rotates in an anti-clockwise sense and cam 26 rotates in a clockwise sense. As illustrated diagrammatically by broken lines in Figure 1, camshaft 22 which carries cam 25 is connected by suitable gearing 55 to the crankshaft 14, so that the camshaft 22 rotates at the same speed as the crankshaft 14. Camshaft 23 is connected by gearing 56 so that it rotates at the same speed as camshaft 22 but in the opposite sense, and moreover with a rotational phase which is adjustable, within limits, with respect to the rotational position of camshaft 22.

This phase adjusting gearing is shown in Figure 4.

To camshaft 22 is secured a gearwheel 57, and to camshaft 23 is secured a similar gearwheel 58. Gearwheel 57 meshes with a first idler gear 59, which in turn meshes with a second, similar, idler gear 61, which in turn meshes with gearwheel 58. First idler gear 59 is carried on a first arm 62 which rotates freely about camshaft 22 and holds idler gear 59 in mesh with gearwheel 57. Second idler gear 61 is carried on a second arm 63 which rotates freely about camshaft 23 and holds idler gear 61 in mesh with gearwheel 58. The free ends of arms 62 and 63 are connected by a link 64, each end of which pivots about the same axis as one of the idler gears 59 and 61. The link 64 holds the two idler gears 59, 61 in mesh. To the arm 63 is solidly secured a regulator lever 65, which rotates, with the arm 63, about the camshaft 23.

Since camshaft 22 is driven from the engine crankshaft to rotate in an anti-clockwise sense, camshaft 23 will be driven, through idler gears 59 and 61, to rotate at the same rotational speed as crankshaft 22, but, of course, in the opposite direction i.e. in a clockwise sense.

It can be shown that adjustment of the rotational position of arm 63 produces a change in the rotational position (i.e. change of phase) of camshaft 23, relative to the angular position of camshaft 22, which is equal to twice the sum of the angular changes in position of arms 62 and 63. The adjustment of arm 63 is conveniently produced, through lever 65, by means of a spring-returned linkage 66 controlled by a cam 67.

A fuller description of the above described gear mechanism for adjusting the relative phase of the two rotating camshafts 22 and 23 will be found in a British Patent specification No. 2 056 570 A. However, such mechanism is believed to pre-date that patent specification.

The arrangement of the present invention is such that the relative phase, i.e. the relative angular position, of cam 26, with respect to cam 25, controls the period for which the valve 16 is open. More specifically, considering the phase of cam 25 to be fixed, it is arranged that cam 25 controls the opening of the valve 16 at a fixed phase in relation to the crankshaft rotation (normally at or just before the top dead centre position of piston 12), whilst cam 26 controls the closing of valve 16. Thus the phase of closing of the valve is controlled by the phase of cam 26.

The centre position 28 of the dual cam-follower lever 27 is its output position, at which it is connected to the intermediate member 29 thereby to operate the valve 16. It will be apparent that the movement of the output position 28 in a vertical direction as illustrated in Figure 2, will represent substan-

tially half of the sum of the vertical movements of the two input positions 31, 32 of the lever, due to their depression by the cams 25 and 26. It is exactly half of this sum when both input positions 31 and 32 are depressed equally by the two cams 25 and 26. The arrangement of the cams 25 and 26, the intermediate member 29, and the lost motion between the latter and the valve 16, is such that the valve 16 is open (i.e. its head 33 is depressed out of contact with its seat 34) only when the centre output position 28 of the lever 27 is depressed by an amount at least equal to that produced by one of the cams 25 and 26 having its "high lift" portion 52 or 54 in contact with its associated lever input position 31 or 32, and that part of the other cam which is in contact with the other of the lever input positions being other than its "low lift" portion 51 or 53. To this end, the two locknuts 39 on the valve stem 35 are adjusted so that when cam 26 is at maximum depression (i.e. "high lift" portion 54 against the cam-follower) and cam 25 is a minimum depression (i.e. "low lift" portion 51 against the cam-follower), there is minimum clearance between the bottom of the intermediate member 29 and the upper locknut 39. Thus any increase in the depression due to rotation of cam 25 will start to open the valve 16, as shown in Figure 3 which shows the valve opening at about piston top dead centre. In other words, the valve 16 is open only when the movement of the cam-follower output position 28 (which is the resultant of the movements of the two input positions 31 and 32) exceeds the maximum clearance between the lower end of of the intermediate member 29 and the upper face of the upper locknut 39, which is the clearance illustrated in Figure 2.

It follows that the length of phase for which the valve 16 is open will depend upon the relative angular phase of the two cams 25 and 26, or, more specifically, the relative angular phase of their two "high lift" portions 52 and 54.

This is illustrated graphically in Figures 5a—5d, in which cam "lift" (or depression) is plotted vertically against crank angle horizontally.

In Figures 5a and 5c, the solid line A represents the lift of cam 25, which is fixed in duration and phase. The broken line E represents the lift of cam 26, which is fixed in duration but adjustable in phase. The valve 16 is fully open only when the two cam lifts 52 and 54 overlap with each other. Figure 5b shows the cam lifts with very little overlap, so that the valve opening, represented by line C, starts just before piston top dead centre, but is of relatively short duration, thus producing a very low cut-off ratio (as hereinbefore defined) for the expansion unit. Figure 5d shows the cam lifts with a relatively large overlap (although not completely in phase with each other). The opening of valve 16 is represented by line D in Figure 5d. It also starts just before top dead centre of the piston, but is of relatively long extent, thus giving a relatively large cut-off ratio for the expansion unit.

It will be seen that the cam 25 controls the opening of the valve 16, and cam 26, the phase of which is adjustable, controls the closing of the valve 16.

The apparatus described in the foregoing example may be incorporated in an engine such as that described in my co-pending application No. (case FAS 2).

CLAIMS

1. Apparatus for controlling the opening and closing of a valve in dependence upon the relative phase of two rotatable cams, comprising:

a dual cam-follower having two input positions spaced apart and adapted to follow the two cams respectively, and an output position spaced apart from each of the aforesaid two input positions and connected to move the valve to open and close,

the movement of the output position representing the sum or resultant of the movements of the two input positions in response to the rotation of the two cams,

there being lost motion between the movement of the output position of the dual cam-follower and the movement of the valve away from its closed position,

such that the valve is open only when the sum or resultant of the movements of the two input positions of the dual cam-follower exceeds a predetermined minimum.

2. Apparatus as claimed in claim 1, including an intermediate member connected between the output position of the dual cam-follower and the valve, there being lost motion between the intermediate member and the valve.

3. Apparatus as claimed in claim 2, in which the dual cam-follower can pivot with respect to the intermediate member at the output position.

4. Apparatus as claimed in any of the preceding claims, in which the dual cam-follower comprises a single lever having the two input positions spaced apart therealong and the output position intermediate the two input positions.

5. Apparatus as claimed in any of the preceding claims, in which the output position is substantially equidistant from each of the two input positions.

6. Apparatus for controlling the opening and closing of a valve, substantially as hereinbefore described with reference to, and illustrated in, the accompanying drawings.

CLAIMS

Amendments to the claims have been filed, and have the following effect:

Claims 1 to 6 above have been deleted or textually amended.

New or textually amended claims have been filed as follows:

1. Apparatus for controlling the opening and closing of a valve in dependence upon the relative phase of two rotatable cams which are respectively mounted fixedly on two separate camshafts, comprising:

a dual cam-follower having two input positions spaced apart and adapted to follow the two cams respectively, and an output position spaced apart from each of the aforesaid two input positions and connected to move the valve to open and close,

the movement of the output position representing the sum or resultant of the movements of the two input positions in response to the rotation of the two cams,

there being lost motion between the movement of the output position of the dual cam-follower and the movement of the valve away from its closed position,

such that the valve is open only when the sum or resultant of the movements of the two input positions of the dual cam-follower exceeds a predetermined minimum.

2. Apparatus for controlling the opening and closing of a valve in dependence upon the relative phase of two rotatable cams, comprising:

two separate camshafts of variable relative phase, each camshaft carrying fixedly one of the two cams,

a dual cam-follower having two input positions spaced apart and adapted to follow the two cams respectively, and an output position spaced apart from each of the aforesaid two input positions and connected to move the valve to open and close,

the movement of the output position representing the sum or resultant of the movements of the two input positions in response to the rotation of the two cams,

there being lost motion between the movement of the output position of the dual cam-follower and the movement of the valve away from its closed position,

such that the valve is open only when the sum or resultant of the movements of the two input positions of the dual cam-follower exceeds a predetermined minimum.

3. Apparatus for controlling the opening and closing of a valve in dependence upon the relative phase of two rotatable cams which are respectively mounted fixedly on two separate camshafts, comprising:

two laterally separated parallel camshafts of variable relative phase, each camshaft carrying fixedly one of the two cams,

a dual cam-follower extending between the camshafts and having two input positions spaced apart and adapted to follow the two cams respectively, and an output position spaced apart from each of the aforesaid two input positions and connected to move the valve to open and close,

the movement of the output position representing the sum or resultant of the movements of the two input positions in response to the rotation of the two cams,

there being lost motion between the movement of the output position of the dual cam-follower and the movement of the valve away from its closed position,

such that the valve is open only when the sum or resultant of the movements of the two input positions of the dual cam-follower exceeds a predetermined minimum.

4. Apparatus as claimed in any of the preceding claims, including an intermediate member connected between the output position of the dual cam-follower and the valve, there being lost motion between the intermediate member and the valve.

5. Apparatus as claimed in claim 4, in which the valve includes a valve member which is axially reciprocable to open and close the valve, and in which the intermediate member is mounted on the valve member for axial movement with respect thereto.

6. Apparatus as claimed in any of the preceding claims, in which the dual cam-follower can pivot with respect to the intermediate member at the output position.

7. Apparatus as claimed in claim 6 when dependant upon claim 5, in which the dual cam-follower is pivotally mounted directly on the intermediate member.

8. Apparatus as claimed in any of the preceding claims, in which the dual cam-follower comprises a single lever having the two input positions spaced apart therealong.

9. Apparatus as claimed in any of the preceding claims, in which the output position is substantially equidistant from each of the two input positions.

10. Apparatus as claimed in any of the preceding claims, in which the two separate camshafts rotate in opposite directions.

11. Apparatus for controlling the opening and closing of a valve, substantially as hereinbefore described with referencce to, and illustrated in, the accompanying drawings.

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